MR No. E6G11

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

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WARTIME REPORT

ORIGINALLY ISSUED

July 1946 as
Memorandum Report E6G11

A PRELIMINARY INVESTIGATION OF THE ICING CHARACTERISTICS OF A LARGE RECTANGULAR-THROAT PRESSURE-TYPE CARBURETOR

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WASHINGTON

E-284

NACA MR No. E6G11

NACA AIRCRAFT ENGINE RESEARCH LABORATORY

MEMORANDUM REPORT

for the

Air Materiel Command, Army Air Forces

A PRELIMINARY INVESTIGATION OF THE ICING CHARACTERISTICS OF A LARGE RECTANGULAR-THROAT PRESSURE-TYPE CARBURETOR

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SUMMARY

A rectangular-throat pressure-type carburetor was investigated to determine the icing characteristics of this part of a large four-engine bomber induction system. Runs of 15-minute duration were made at a simulated low-cruising power condition over a range of carburetor-air temperatures from 12° to 100° F with varied moisture contents to establish the limiting conditions for the formation of visible and serious icing. The investigation included icing tests made with a standard nozzle bar and an impinging-jets nozzle bar.

The results showed that serious ice did not form in the carburetor under the conditions of this investigation, although visible ice was formed on the carburetor nozzle bar and center rib at carburetor-air temperatures varying from 12° to 87° F and with relative humidities as low as 23 percent. Frost was formed on the forward throttle plate during one of the runs. The standard nozzle bar and the impinging-jets nozzle bar showed approximately the same icing characteristics.

Some of the simulated rain that impinged upon the impact tubes at the mouth of the carburetor drained into the pressure-meter chamber and, in a few hours, the quantity collected seriously reduced the fuel-air ratio.

INTRODUCTION

The investigation of the icing characteristics of a large rectangular-throat pressure-type carburetor was conducted at the NACA Cleveland laboratory at the request of the Air Materiel

Command, Army Air Forces. Carburetor ice may consist of any or all of three general types: impact, throttling, and fuel-evaportion ice. Impact ice is formed at intake-air temperatures below 32° F when water impinges on the cold surfaces of the induction system. Throttling ice results from the pseudoadiabatic expansion of combustion air through the metering venturis and past the throttle plates of the carburetor. Fuel-evaporation ice, which probably occurs most frequently in operation, forms when water in the air stream freezes as the result of the cooling effect of fuel evaporation and may occur in some installations at outside-air temperatures as high as 100° F.

Research was undertaken to determine the particular icing characteristics of the carburetor as a unit, isolated from the other component parts of the airplane induction system. Tests were conducted using the standard nozzle bar (fig. 1(a)), and an impinging-jets nozzle bar (fig. 1(b) and (c)) developed by the NACA for the improvement of fuel distribution. The range of the investigation was limited by the capacity of the refrigerated-air supply to a simulated low-cruising power with the following approximate conditions: horsepower, 1170; air flow, 8000 pounds per hour; and fuel-air ratio, 0.0825. Carburetor-air temperatures from 12° to 100° F were used with various water contents to determine the limiting-icing characteristics of the carburetor. Impact-icing conditions were not investigated because it is believed that this type of ice would only be formed in the airplane induction system ahead of the turbosupercharger and an investigation utilizing the entire induction system was beyond the scope of the available laboratory equipment.

APPARATUS

The carburetor used in this investigation was a hydrometering-type pressure carburetor with a bottom deck area of 58 square inches and was intended for use on an 18-cylinder engine with 3350-cubic-inch displacement. It was mounted on the rear accessory section of an 18-cylinder engine having a displacement of 2800 cubic inches in which the supercharger impeller was driven by an electric dynamometer. Plastic observation windows were located in the specially constructed adapter and in the connecting duct above the carburetor. All observations were necessarily made through the plastic windows because it was impossible to remove the carburetor for inspection before the ice accretions had melted. The carburetor installation is shown in figure 2.

Provisions were available for regulating temperature and flow of the fuel and the water used for simulating rain and for controlling temperature, humidity, pressure, and flow of the refrigerated air. A detailed description of this equipment appears in reference 1.

The fuel and water systems were so installed that the liquids could be bypassed during the intervals between runs. Thus, the conditions for each run could be established without encountering icing before the run was begun. Fuel conforming to specification AN-F-22 (62 octane) was used throughout the investigation.

Because the maximum obtainable air flow was limited by the size of the ducts through which the supply air was drawn, the investigation was restricted to a simulated low-cruising power condition.

TEST PROCEDURE

Previous to the start of each run, the following conditions were established: air flow, 8000 pounds per hour; fuel flow, 660 pounds per hour; fuel temperature, 40° F; manifold pressure, approximately 32 inches of mercury absolute; and pressure altitude at the carburetor deck, approximately 4200 feet. In addition, the desired air temperature and humidity were also established.

When the conditions had stabilized, the fuel and the water were introduced into the carburetor and an initial set of readings was recorded; subsequent readings were taken every 3 minutes for the duration of the 15-minute run. The following data were recorded: air flow, fuel flow, dry-bulb temperature and dew-point temperature of the entering air, carburetor top-deck pressure, manifold pressure, pressure drop across the carburetor, carburetor metering-suction differential, fuel temperature, and supercharger-outlet temperature. When rain was simulated, the water flow and temperature were also recorded. At the end of each run, the carburetor was carefully inspected for the presence of ice before and after fuel injection was stopped.

RESULTS AND DISCUSSION

The results of this investigation showed that the standard and the impinging-jets nozzle bars have approximately the same icing characteristics. The data are plotted on coordinates of carburetor-air temperature and water content in figure 3 and on coordinates of carburetor-air enthalpy and water content in figure 4. The curves define the approximate limiting conditions for the formation of visible ice of only the fuel-evaporation type. Visible ice was formed at carburetor-air temperatures ranging from 12° to 87° F and with relative humidities as low as 23 percent.

No serious icing of the carburetor was encountered during this investigation. Because severe ice accretions accumulated rapidly in the air passage below the carburetor, full 15-minute icing runs could not be made at low temperatures with high water contents. Serious ice might have been formed in the carburetor at temperatures below 40° F with water contents in excess of saturation.

With one exception, all carburetor-ice formations occurred on the nozzle bar and on the supporting rib that extends from front to rear across the middle of the carburetor. The ice formations increased from a relatively thin layer on the top of the nozzle bar and sides of the rib to a maximum thickness of approximately one-half inch on the bottom surfaces. A characteristic ice formation on the nozzle bar is shown in the schematic diagram of the carburetor (fig. 5). The heaviest ice was encountered with high moisture contents over a range of temperatures from 30° to 40° F.

At the end of one run there was a very light coating of frost on the forward throttle plate. It was observed that ice, which was built up on the bottom of the nozzle bar to a thickness of about one-half inch, caused the fuel spray to be deflected outward. A very small portion of the fuel was probably carried upward by the turbulent air beneath the throttle plates where the resultant cooling due to fuel evaporation caused the formation of light frost.

A run of several hours' duration was attempted to determine whether serious ice formations could be built up in the carburetor during extended periods of operation. At the end of 45 minutes, however, the ice on the turning vanes at the supercharger inlet had become so heavy that it was necessary to terminate the test. Only a very small amount of ice was visible on the carburetor nozzle bar.

Near the end of the investigation of the standard nozzle bar, the flow of fuel through the carburetor could not be maintained and a subsequent flow-bench check showed that the carburetor metering was far below the minimum specifications. Disassembly of the carburetor revealed that approximately 60 cubic centimeters of water had accumulated in the pressure metering system. At the time this difficulty occurred, a total of seven 15-minute runs had been made using simulated rain at an average injection rate of 200 grams per minute. During the investigation of the impinging-jets nozzle bar, only one 15-minute run was made using simulated-rain injection. When the carburetor was checked at the completion of the investigation, approximately 9 cubic centimeters of water were drained from the pressure meter.

Water apparently entered the impact tubes located across the top of the carburetor and drained through the connecting passage to the pressure meter (fig. 5). No drains are provided in the metering system of the carburetor; consequently, water collected in the pressure meter and fuel metering was affected. It is not anticipated that this characteristic of the carburetor will be hazardous in the operation of the airplane because leakage of ingested rain from the ducting, collection in the intercooler, and vaporization in the turbosupercharger should prevent any water from reaching the carburetor.

SUMMARY OF RESULTS

The following results are applicable only to the large rectangular-throat pressure-type carburetor when operated at a simulated low-cruising power condition over a range of carburetor-air temperatures from 12° to 100° F with varied moisture contents:

1. Visible ice was formed on the carburetor nozzle bar and center rib at carburetor-air temperatures varying from 12° to 87° F and with relative humidities as low as 23 percent.

2. Ice did not form in the carburetor in quantities large enough to adversely affect engine operation within 15 minutes.

3. Frost was formed on the forward throttle plate during one of the runs.

4. A standard and an impinging-jets nozzle bar had approximately the same icing characteristics.

5. Some of the water that impinged upon the mouth of the carburetor impact tubes drained into the pressure-meter chamber and in a few hours the quantity collected seriously reduced the fuel-air ratio.

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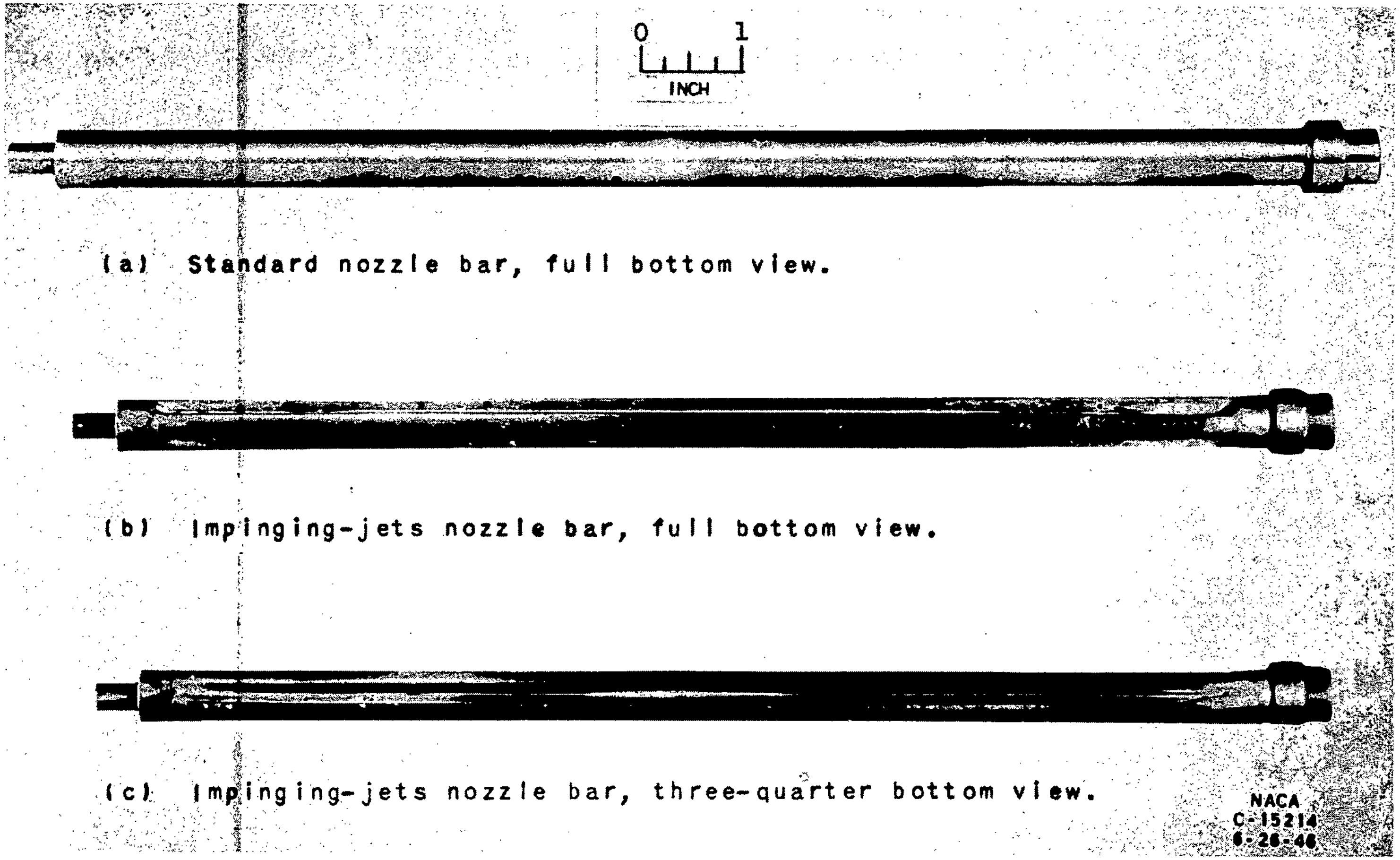
REFERENCE

1. Mulholland, Donald R., Rollin, Vern G., and Galvin, Herman B.: Laboratory Investigation of Icing in the Carburetor and Supercharger Inlet Elbow of an Aircraft Engine. I - Description of Setup and Testing Technique. NACA MR No. E5L13, 1945.



(a) Standard nozzle bar, full bottom view.

(b) Impinging-jets nozzle bar, full bottom view.

(c) Impinging-jets nozzle bar, three-quarter bottom view.

Figure 1. – Nozzle bars used in carburetor icing investigation.

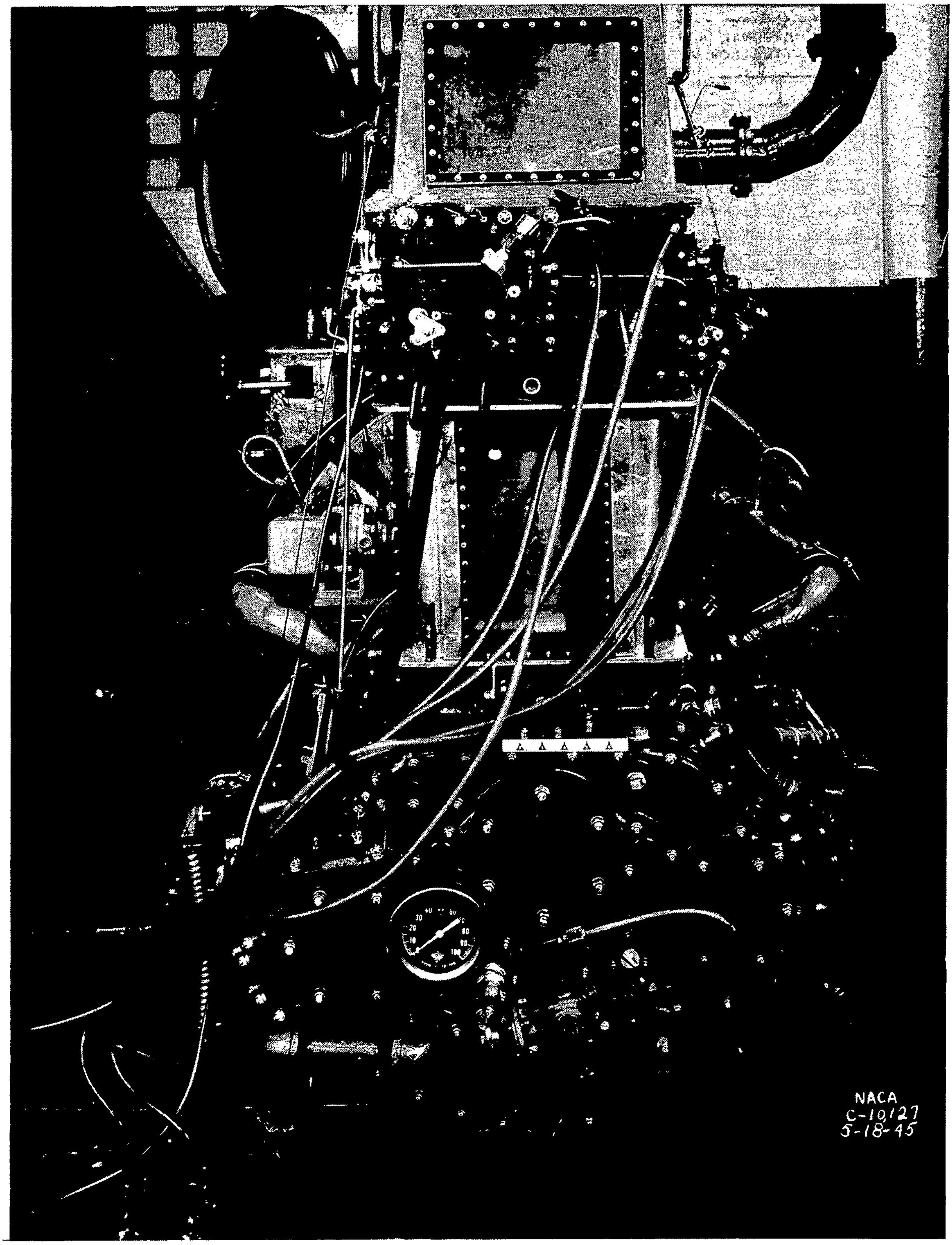


Figure 2. - Rear view of installation used for carburetor icing investigation.

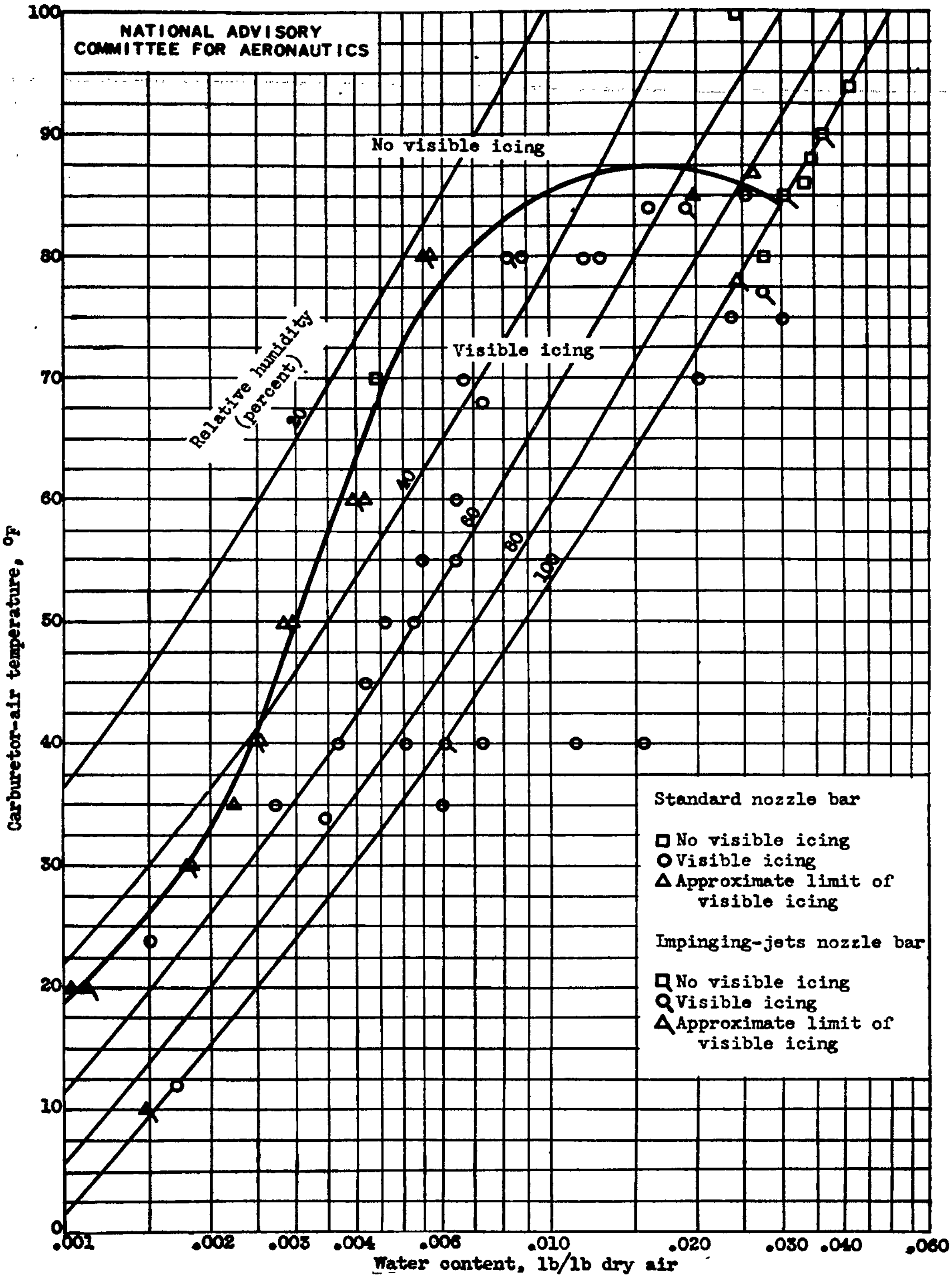


Figure 3. - Limiting icing conditions of temperature and water content at low-cruising power. Rectangular-throat pressure-type carburetor; air-flow rate, 8000 pounds per hour; fuel-air ratio, 0.082; pressure altitude at carburetor deck, 4200 feet.

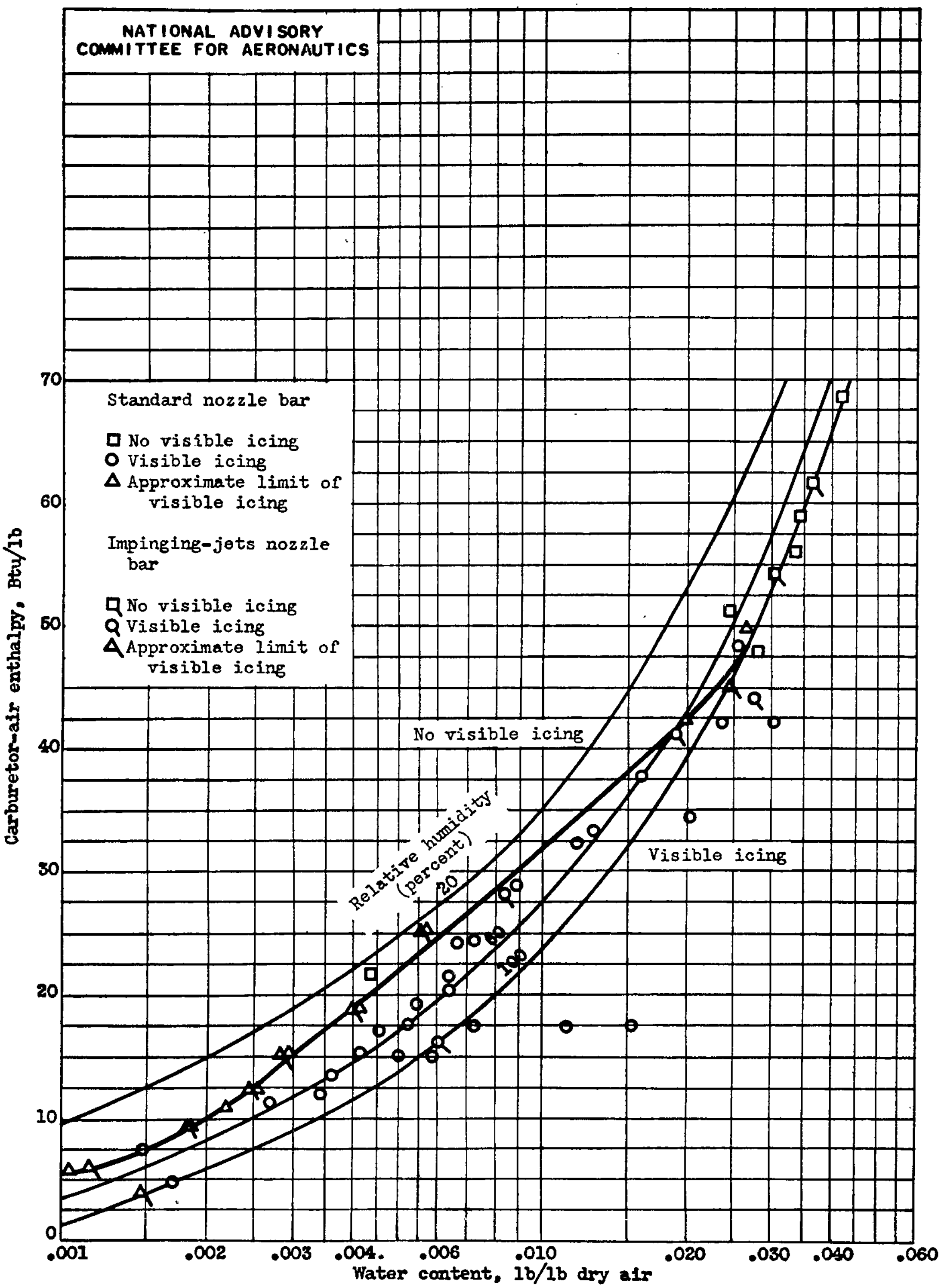


Figure 4. - Limiting icing conditions of enthalpy and water content at low-cruising power. Rectangular-throat pressure-type carburetor; air-flow rate, 8000 pounds per hour; fuel-air ratio, 0.082; pressure altitude at carburetor deck, 4200 feet.

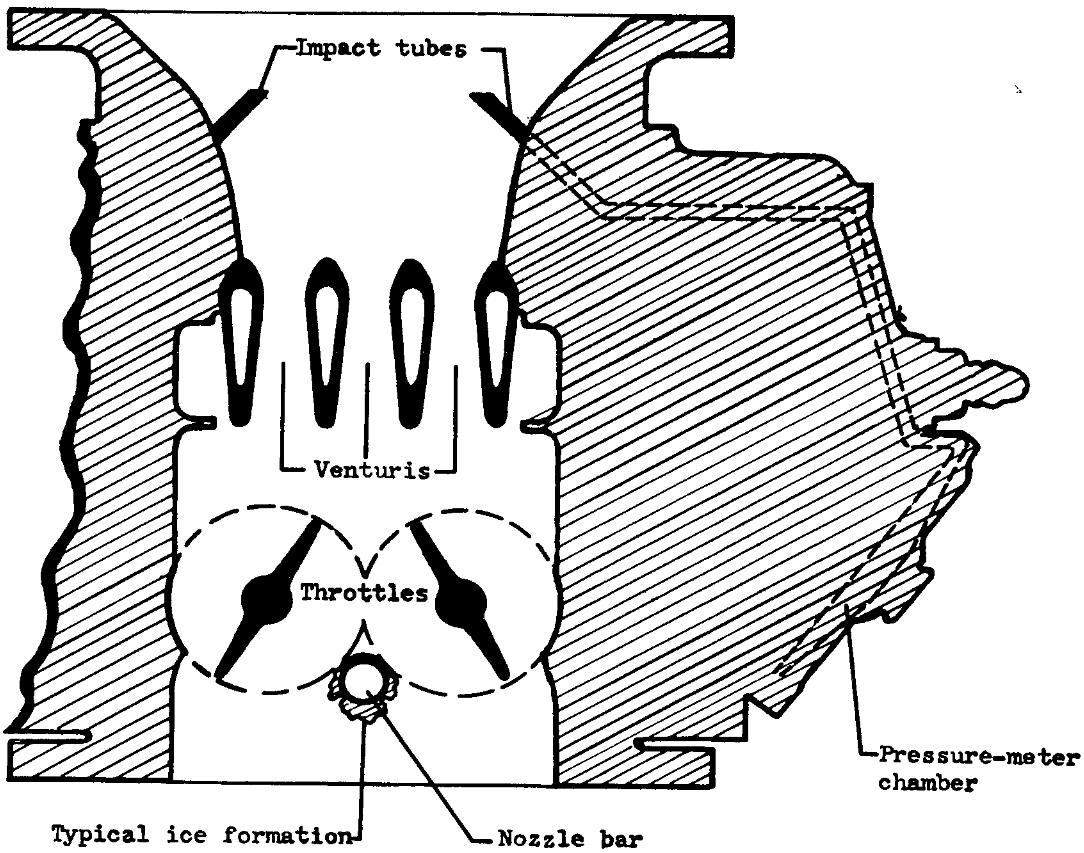


Figure 5. - Schematic diagram of large rectangular-throat pressure-type carburetor.